

# Transmutation Reactions Induced by D<sub>2</sub> Gas Permeation through Pd Complexes (Pd/CaO/Pd)

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10-15 August 2008, Washington DC, USA*

## **1. Introduction**

## **2. Experimental method and the Results so far**

## **3. Experimental Results and Discussion**

**3-1 Experiments for in-situ measurement at Spring-8**

**3-2 Identification of Products by the energy scan XRF**

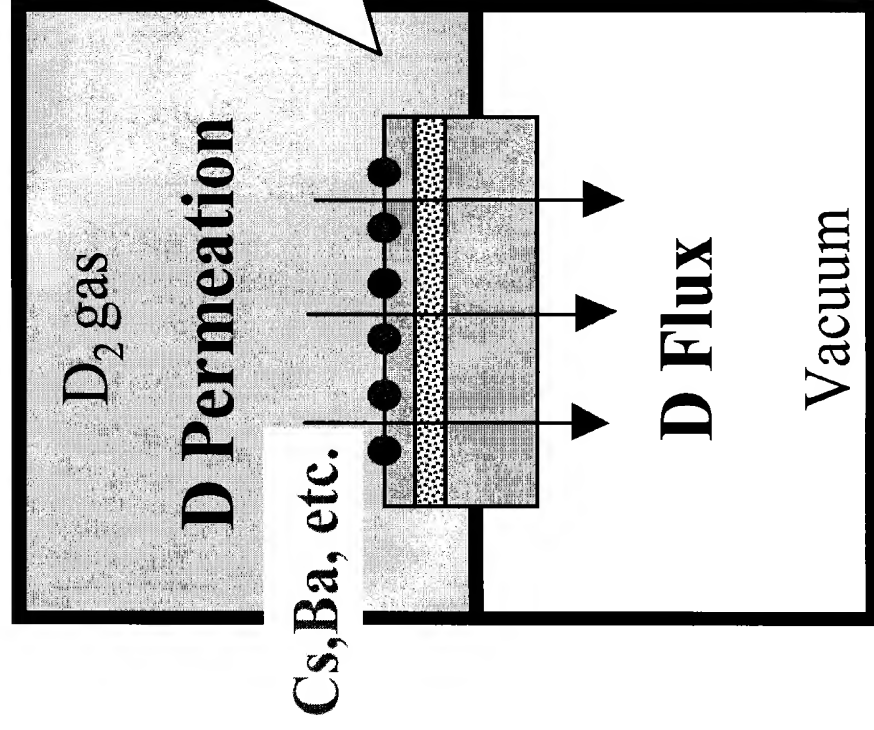
**3-3 Effect of gradient T for deuterium density**

## **4. Concluding Remarks**

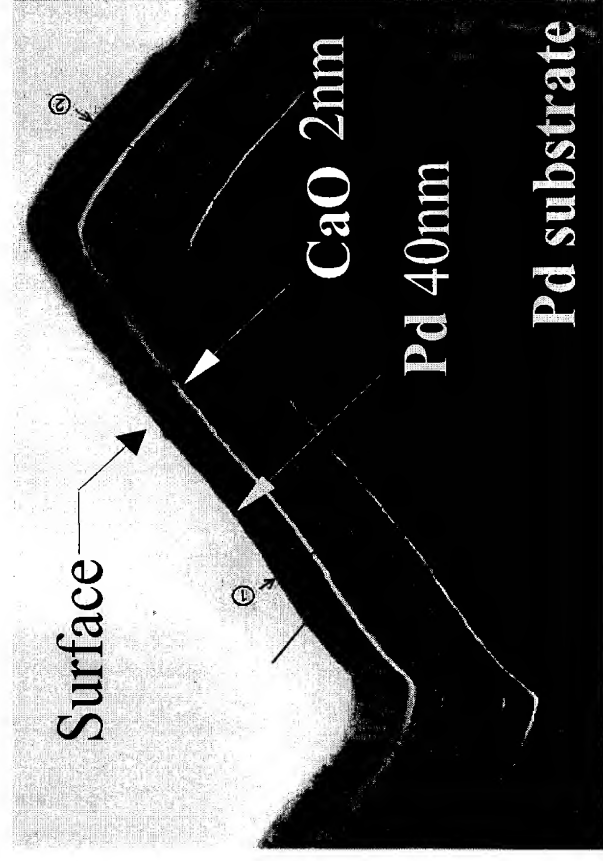
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# Features of the Present Method

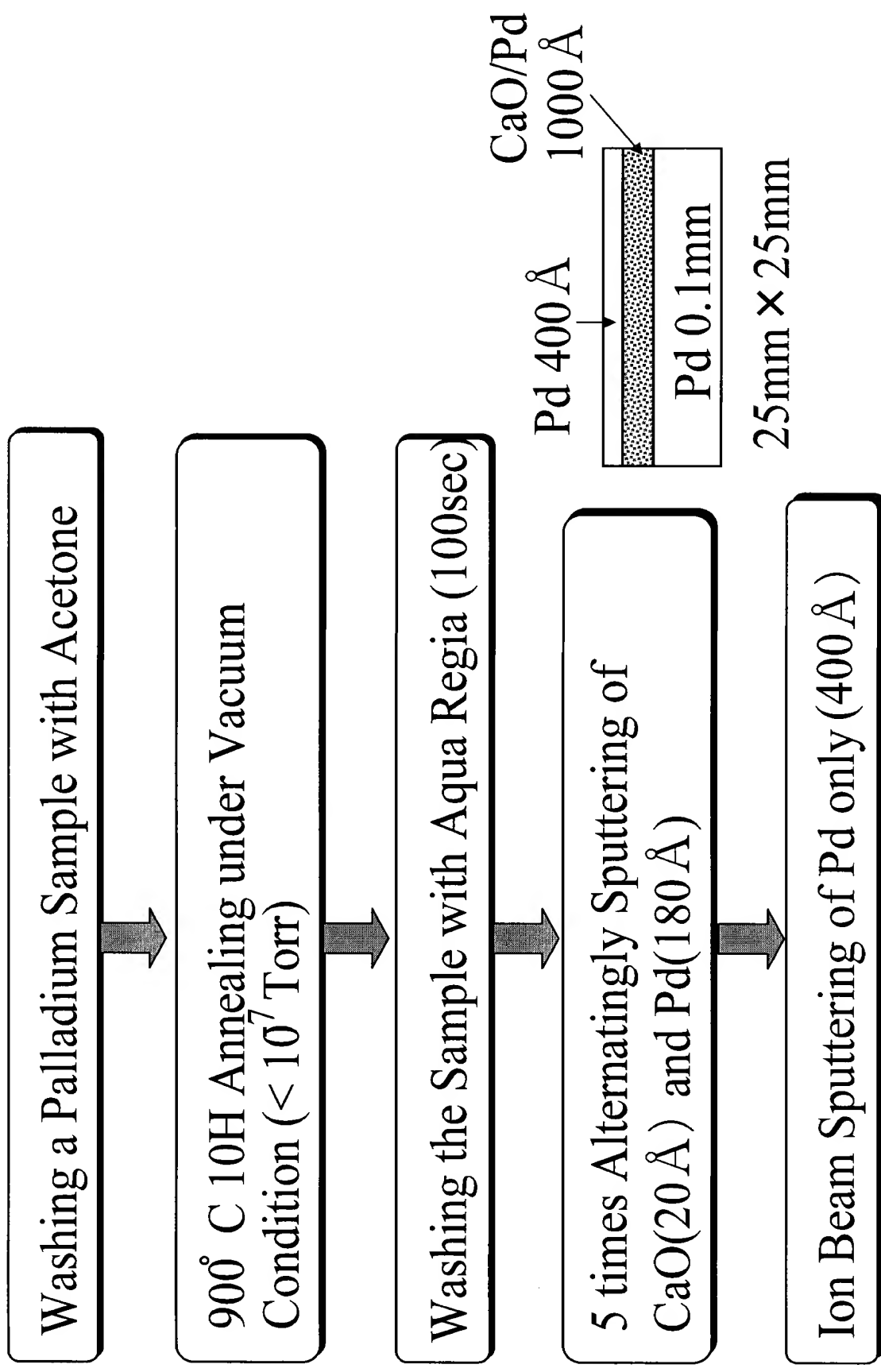
## D<sub>2</sub> gas permeation through the Pd complex

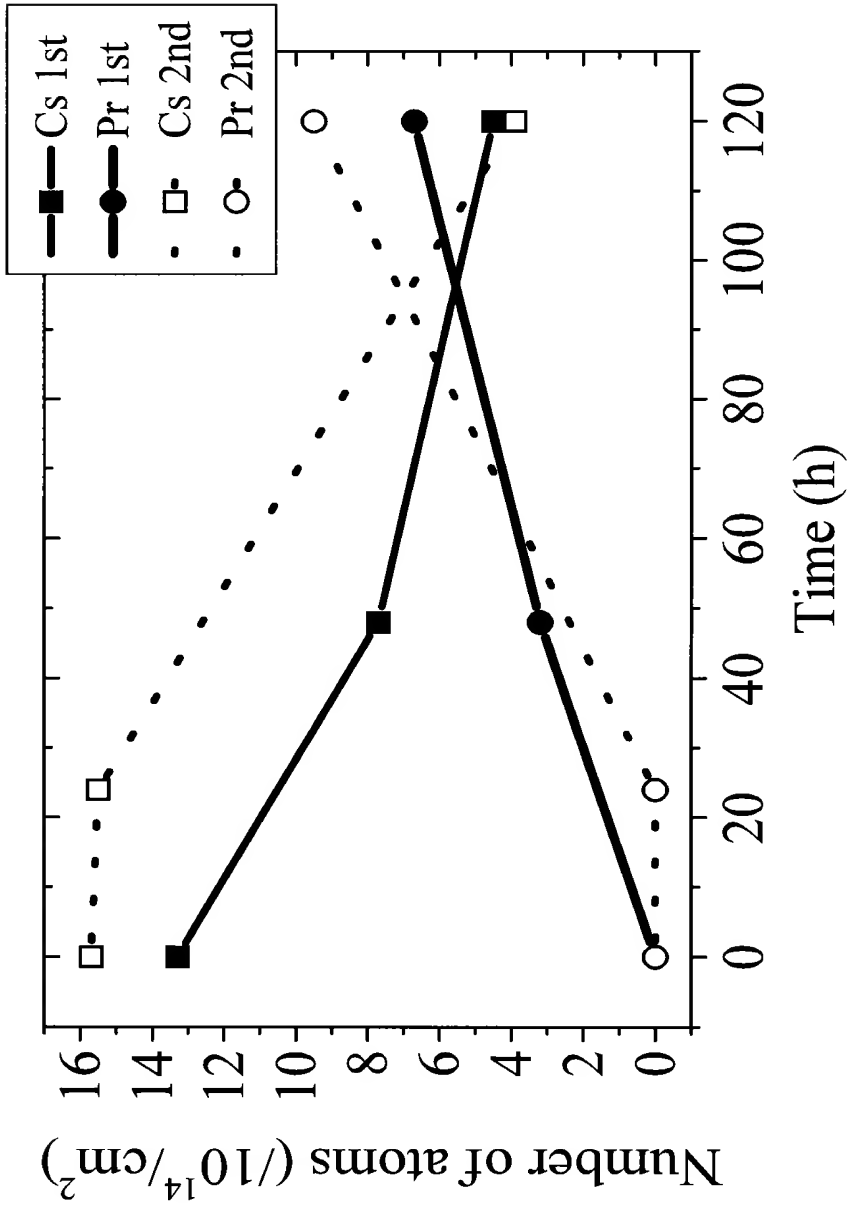
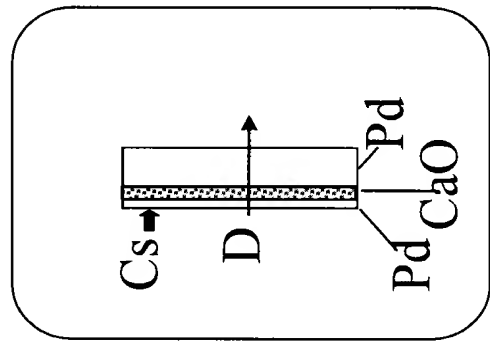


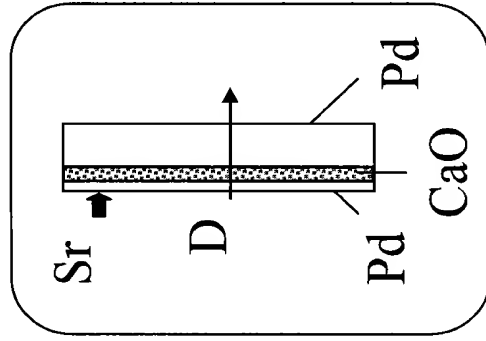
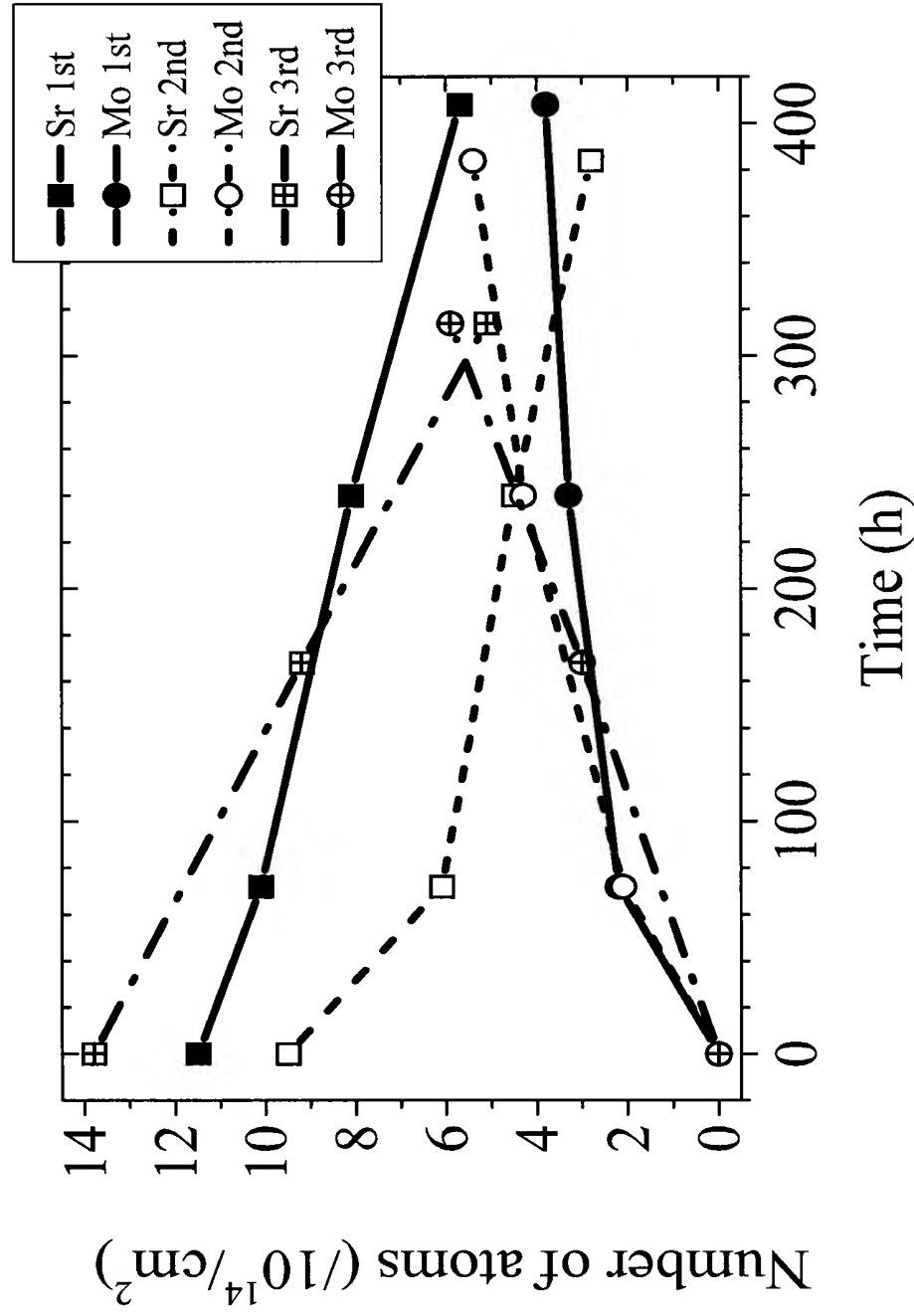
Cross Section of Pd Complex



# Fabrication of Pd Complex

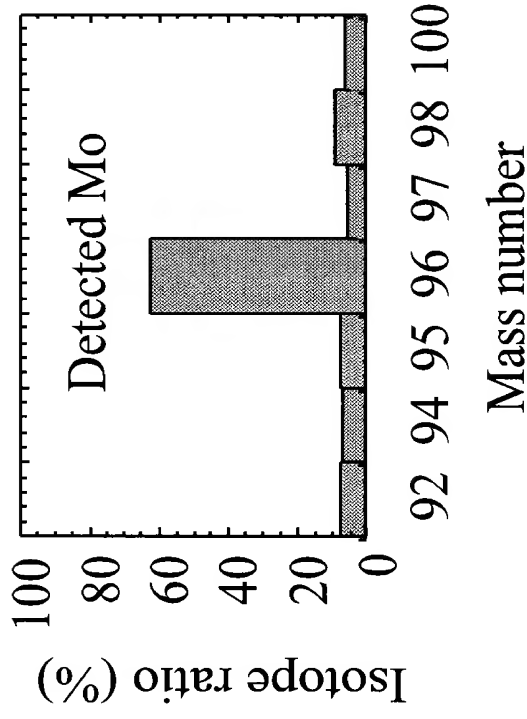
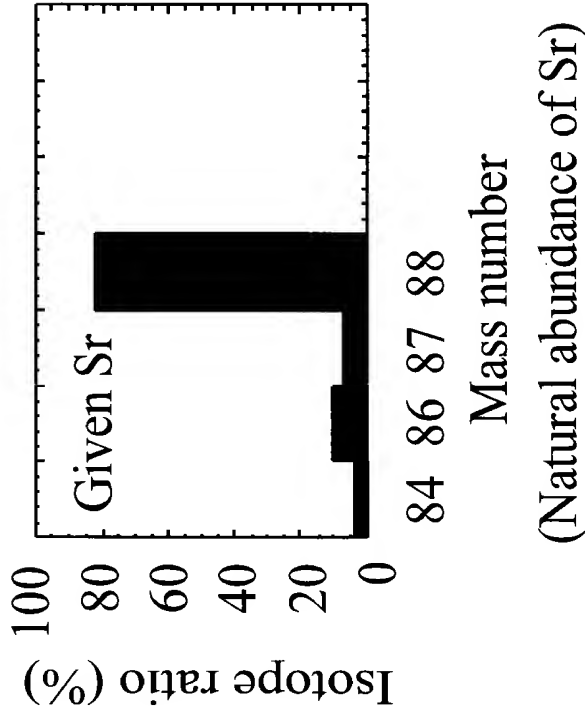




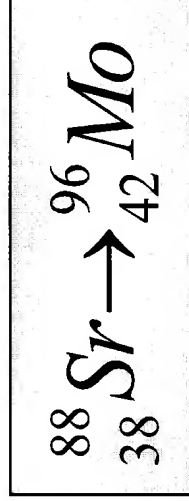


# Relation of Isotopic Composition

## between Sr and Mo

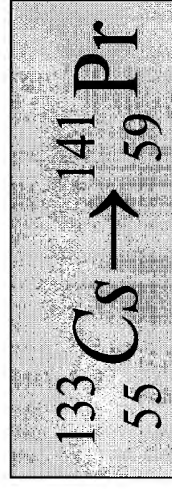


Mass N. +8



Atomic N. +4

Mass N. +8

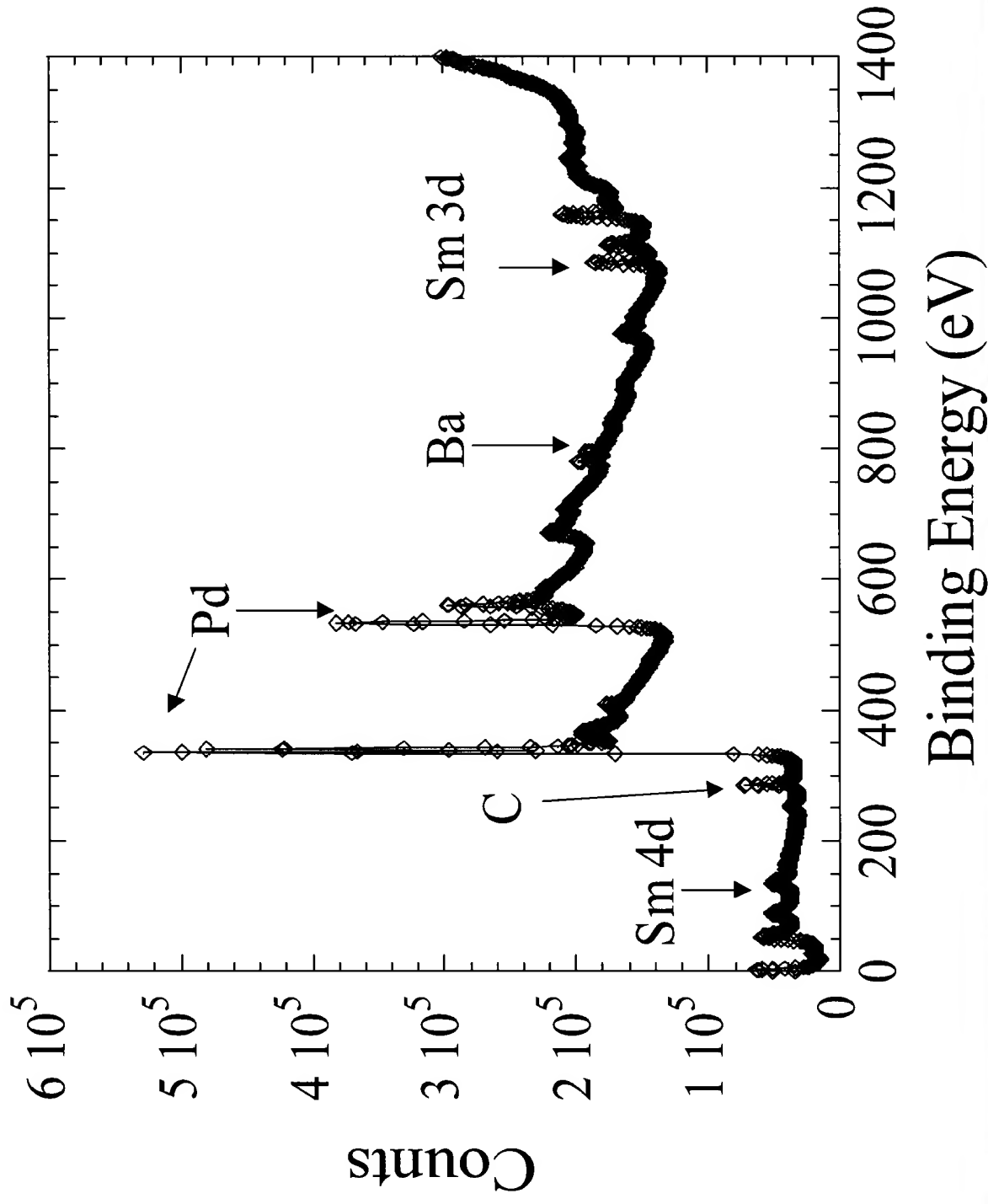


Atomic N. +4



# Transmutation of Ba into Sm;

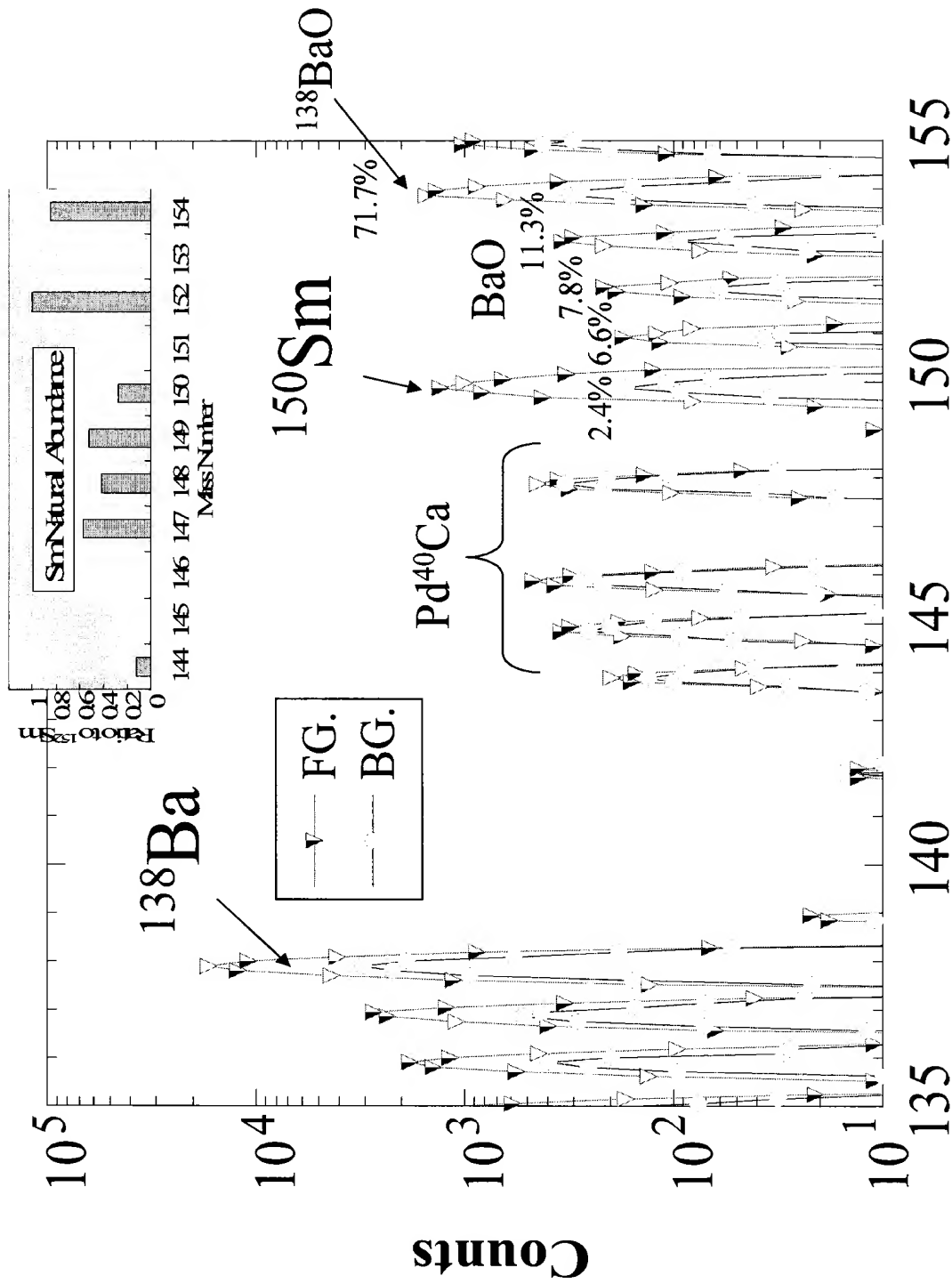
## Natural Ba





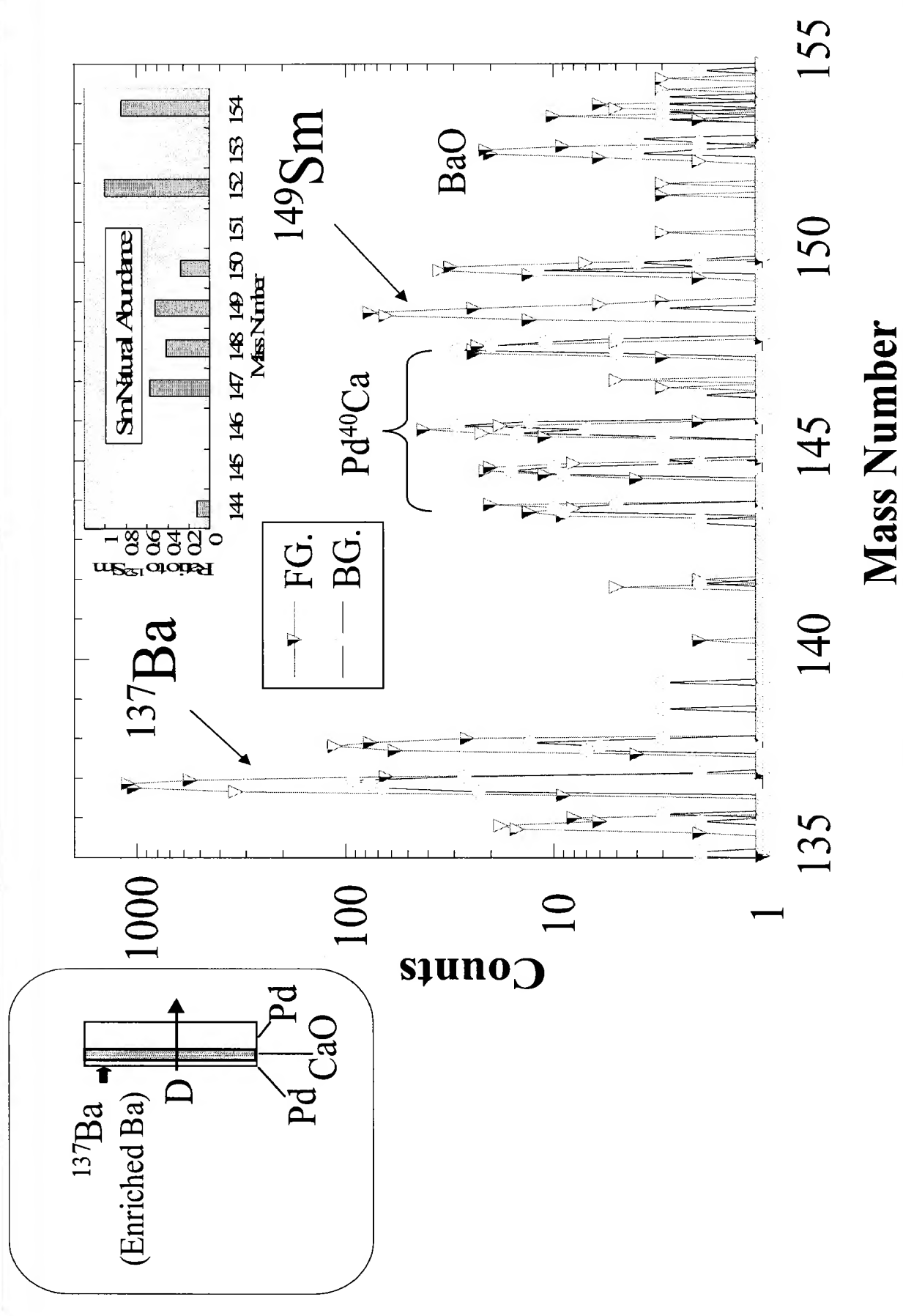
# SIMS Spectra for a Natural Ba Experiment


**HITACHI**  
 ANALYTICAL INSTRUMENTS, LTD.  
 TECHNICAL HEADQUARTERS



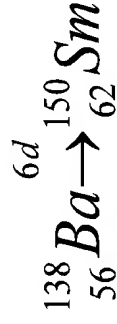
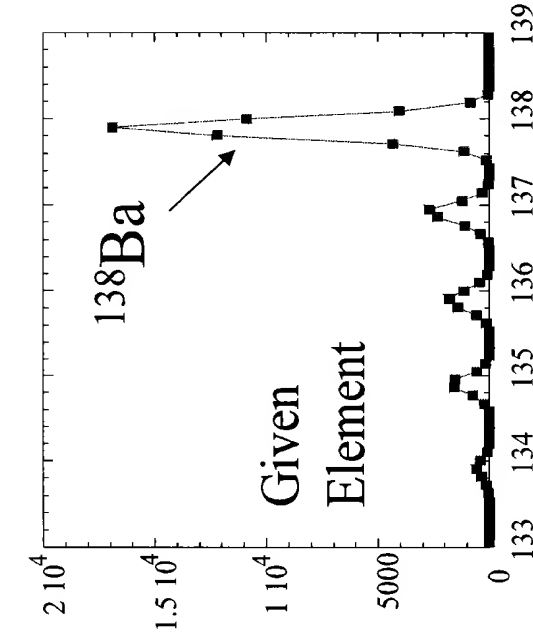
Mass Number

# SIMS Spectra for $^{137}\text{Ba}$ Exp.

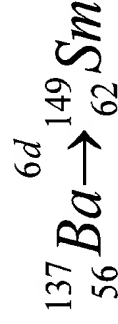
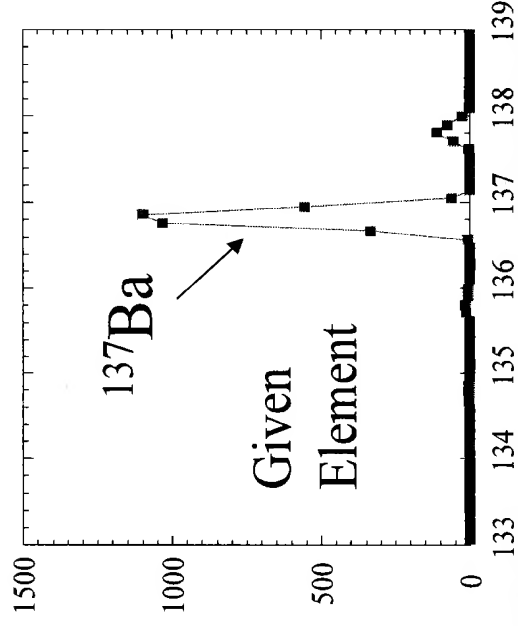
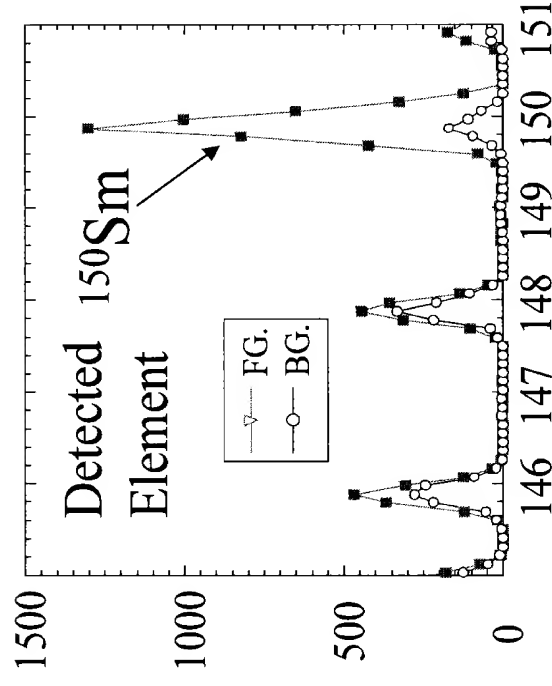


# Mass Correlation between

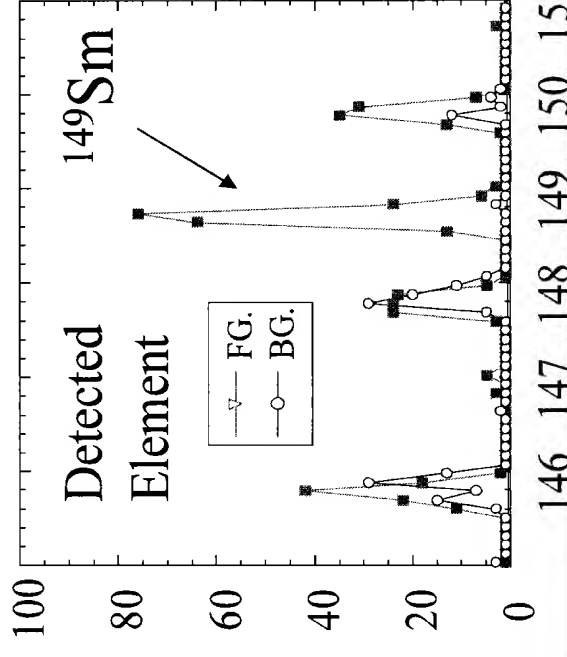
## Given and Detected Elements



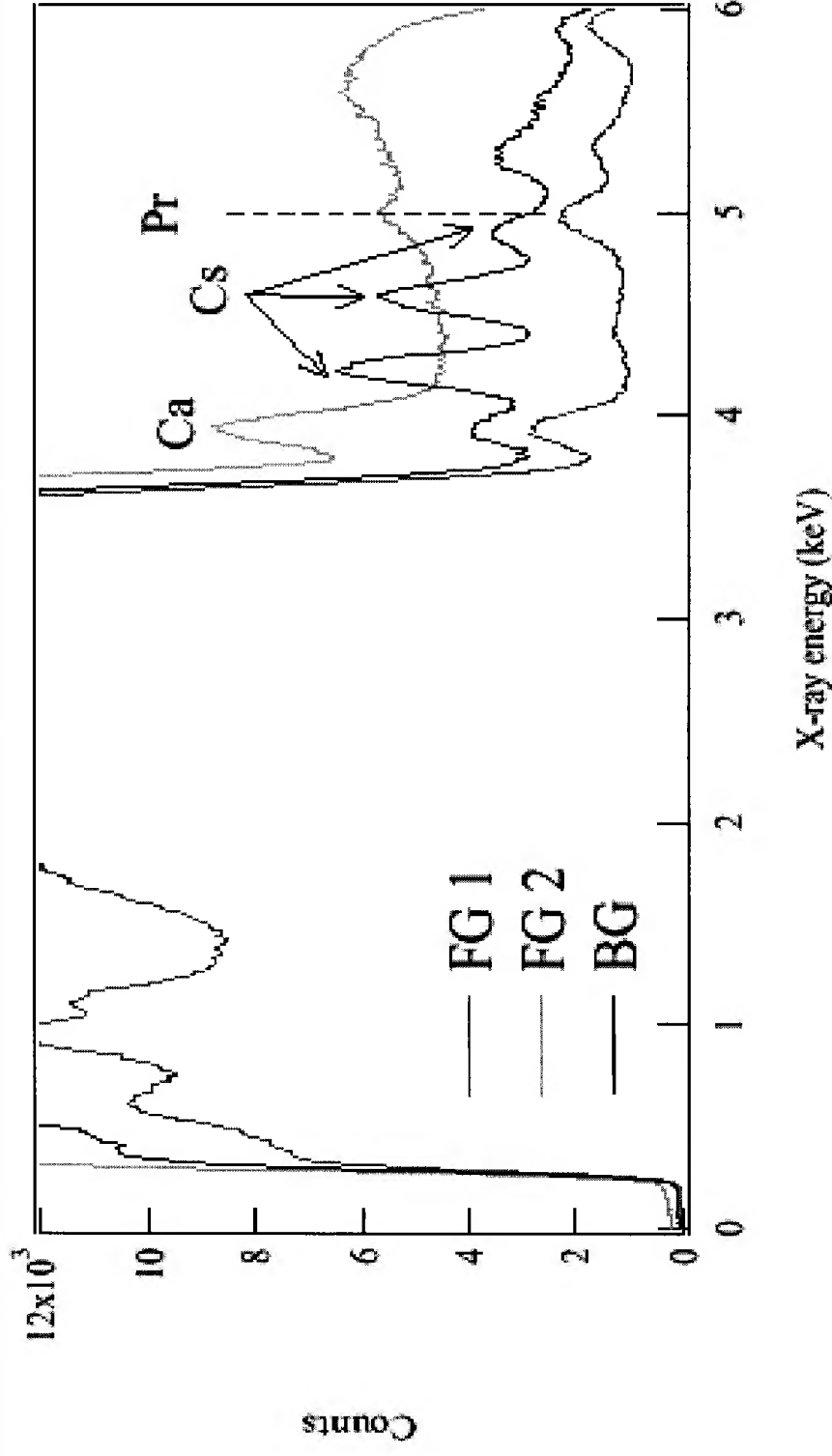
$$\begin{matrix} M + 12 \\ Z + 6 \end{matrix}$$



$$\begin{matrix} M + 12 \\ Z + 6 \end{matrix}$$



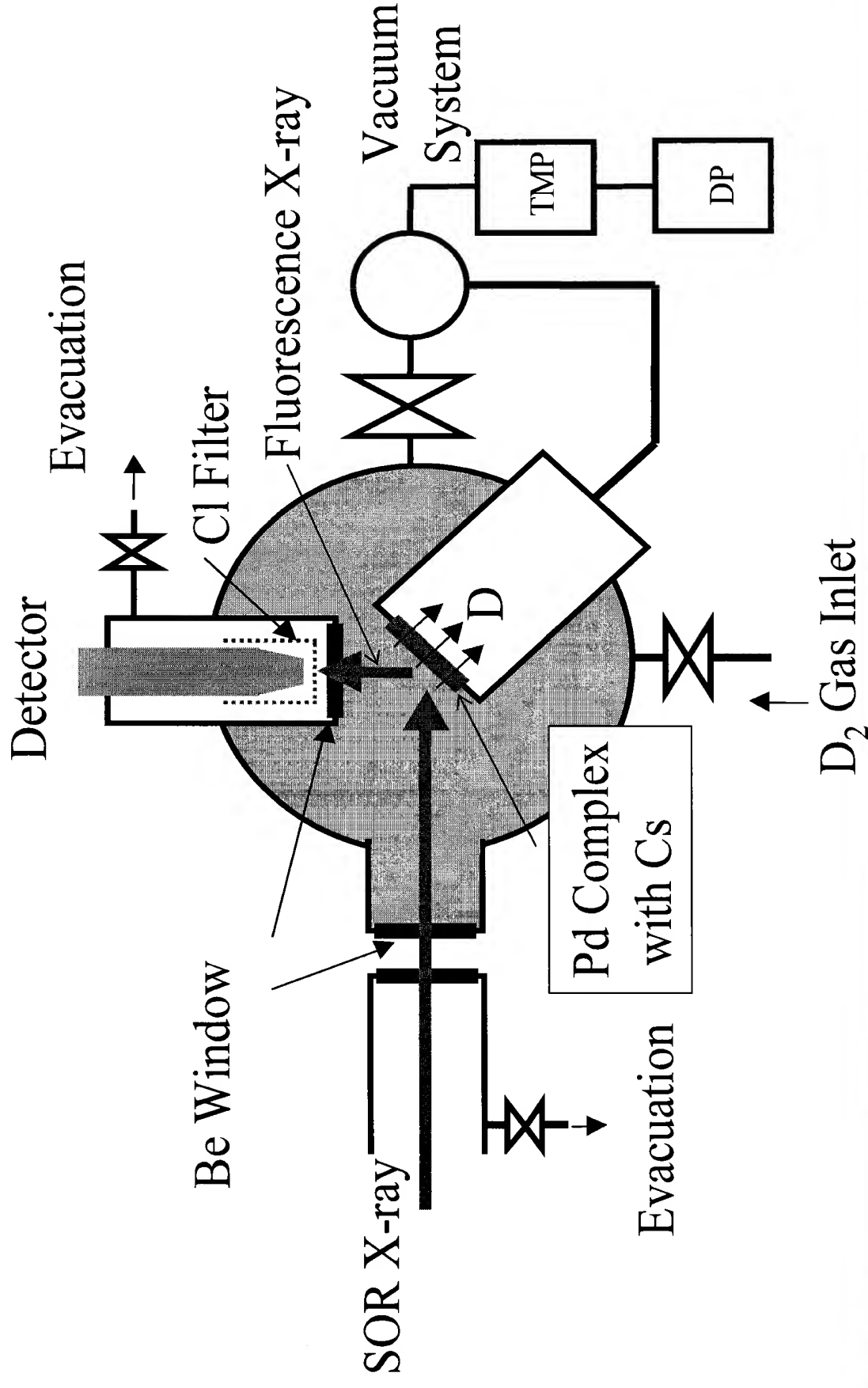
# Identification of Pr by XRF (2003)



Detection of Pr using SOR X-ray at Spring-8, Harima, Japan  
(FG1,FG2:Signals from Samples after D2 Permeation  
BG:Signals from the sample before Permeation)

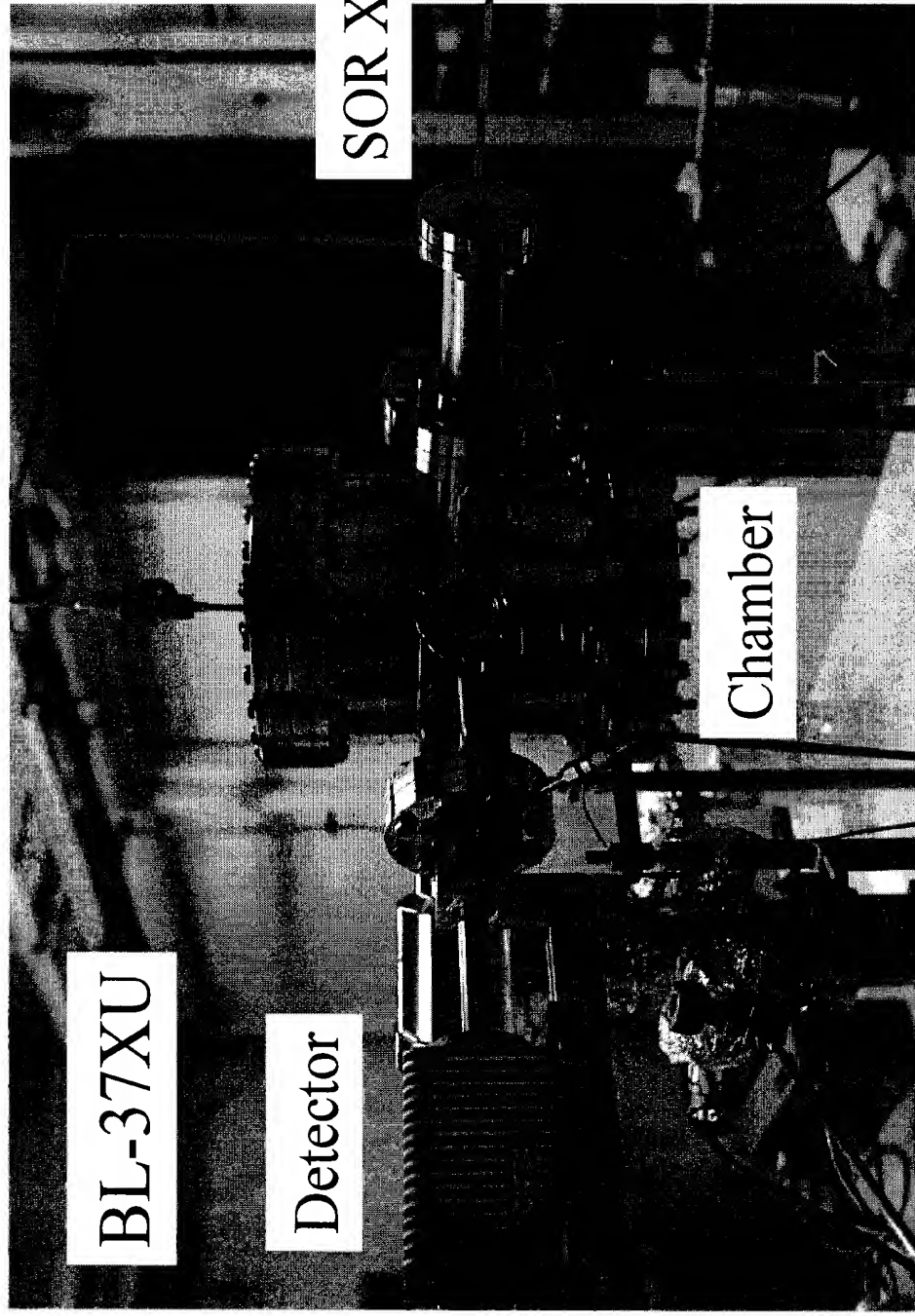
# Experimental Set-up for *in-situ*

## Measurement located at SPRing-8

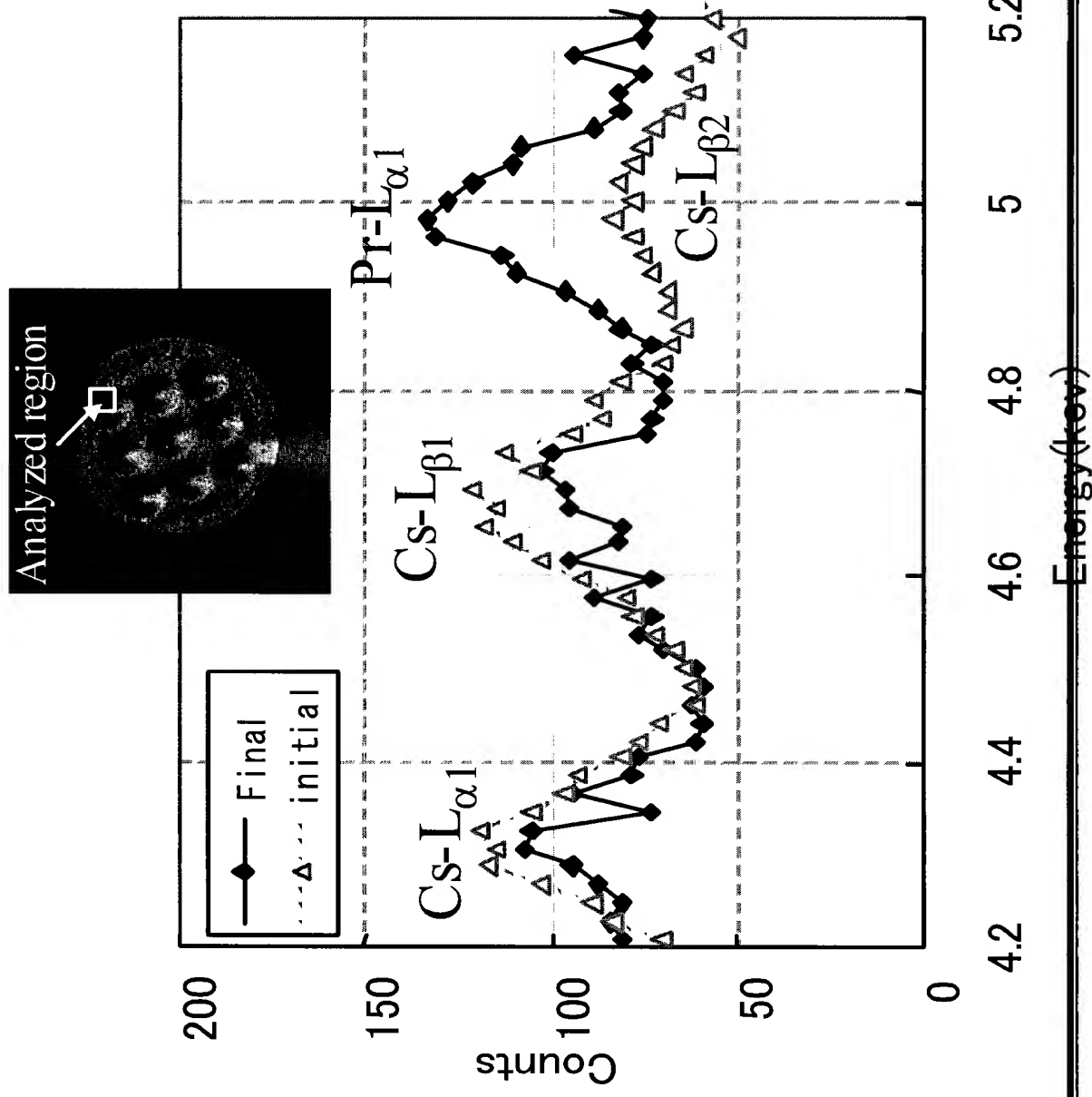


# Photograph of the Experimental Set-up

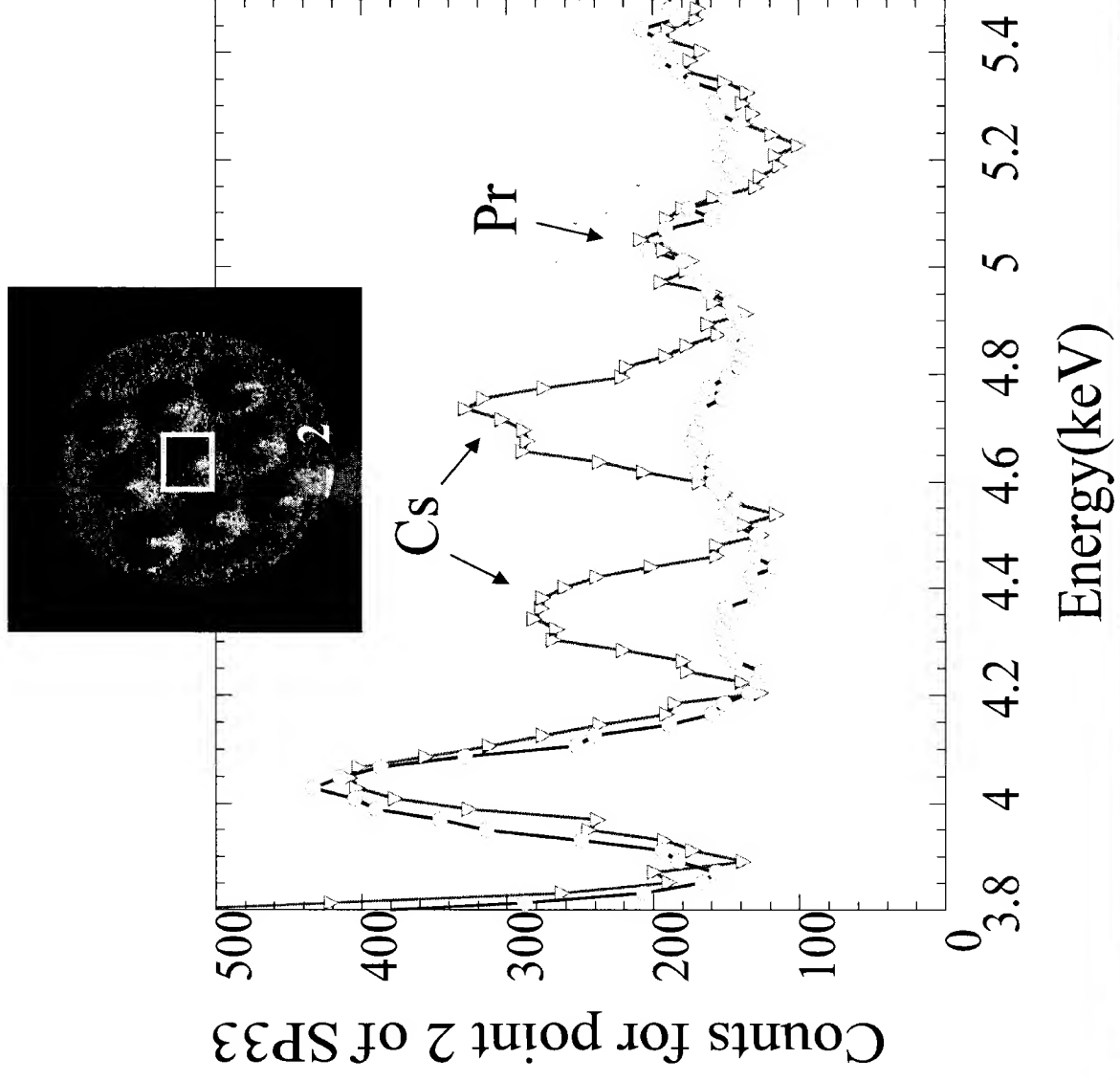
**MITSUBISHI**  
NAVY INDUSTRIES, LTD.  
TECHNICAL HEADQUARTERS



# Detection of Pr; SP-24



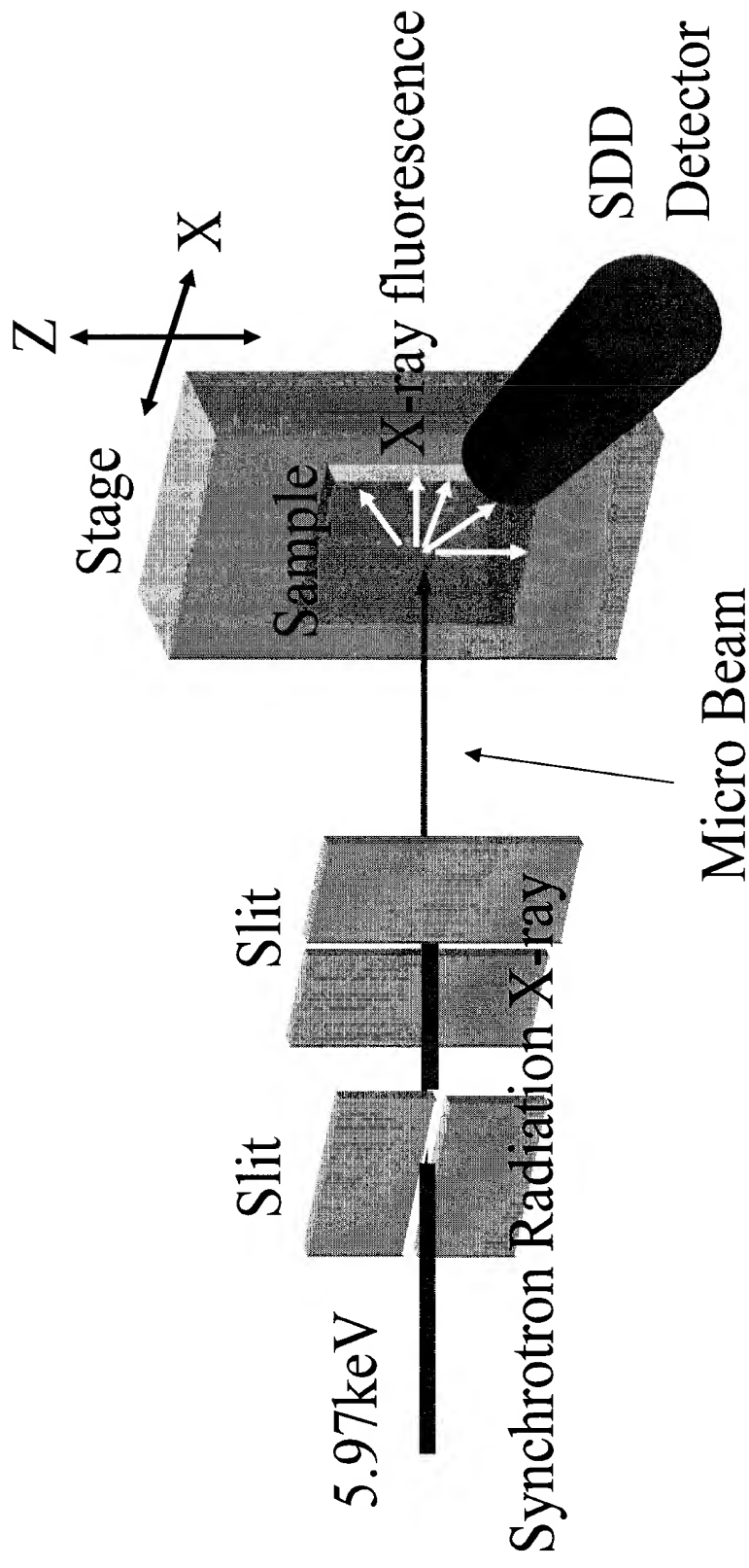
# Detection of Pr; SP-33





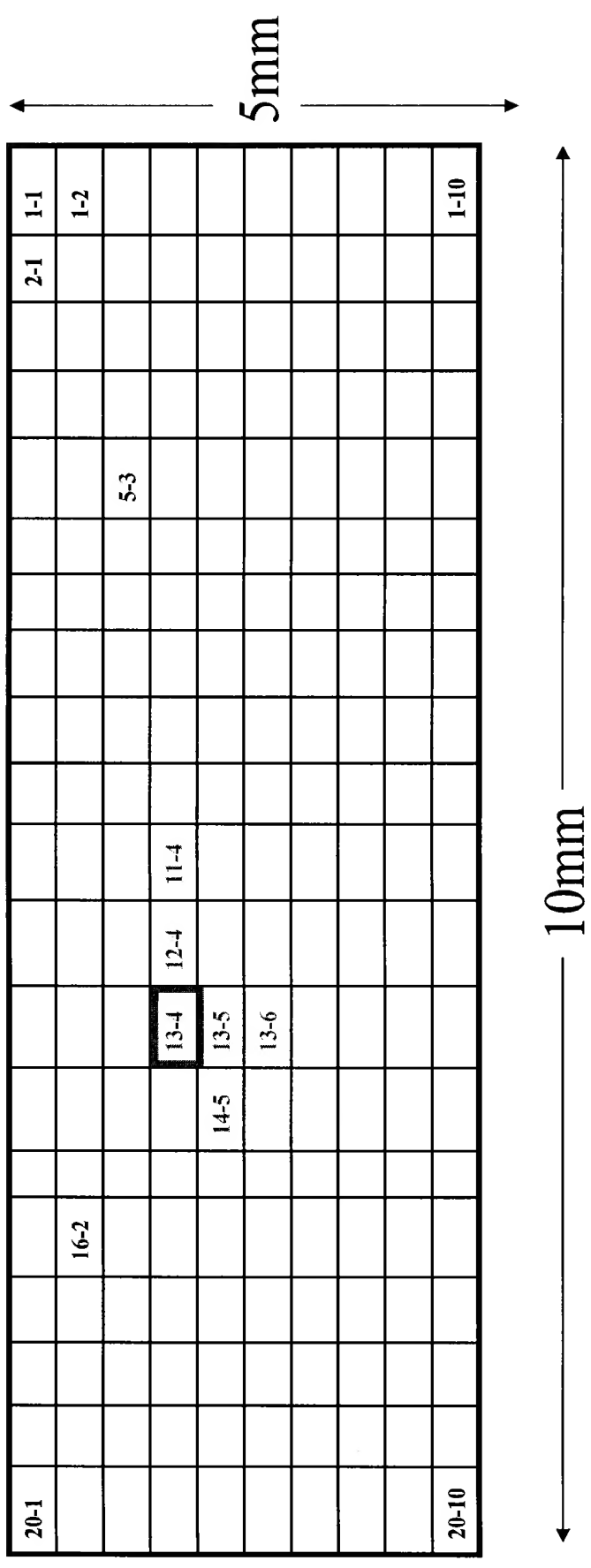
# Experimental Setup for Measurement of Pr Distribution

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# Mapping of Products by 500 micron MITSUBISHI HEAVY INDUSTRIES, LTD. TECHNICAL HEADQUARTERS

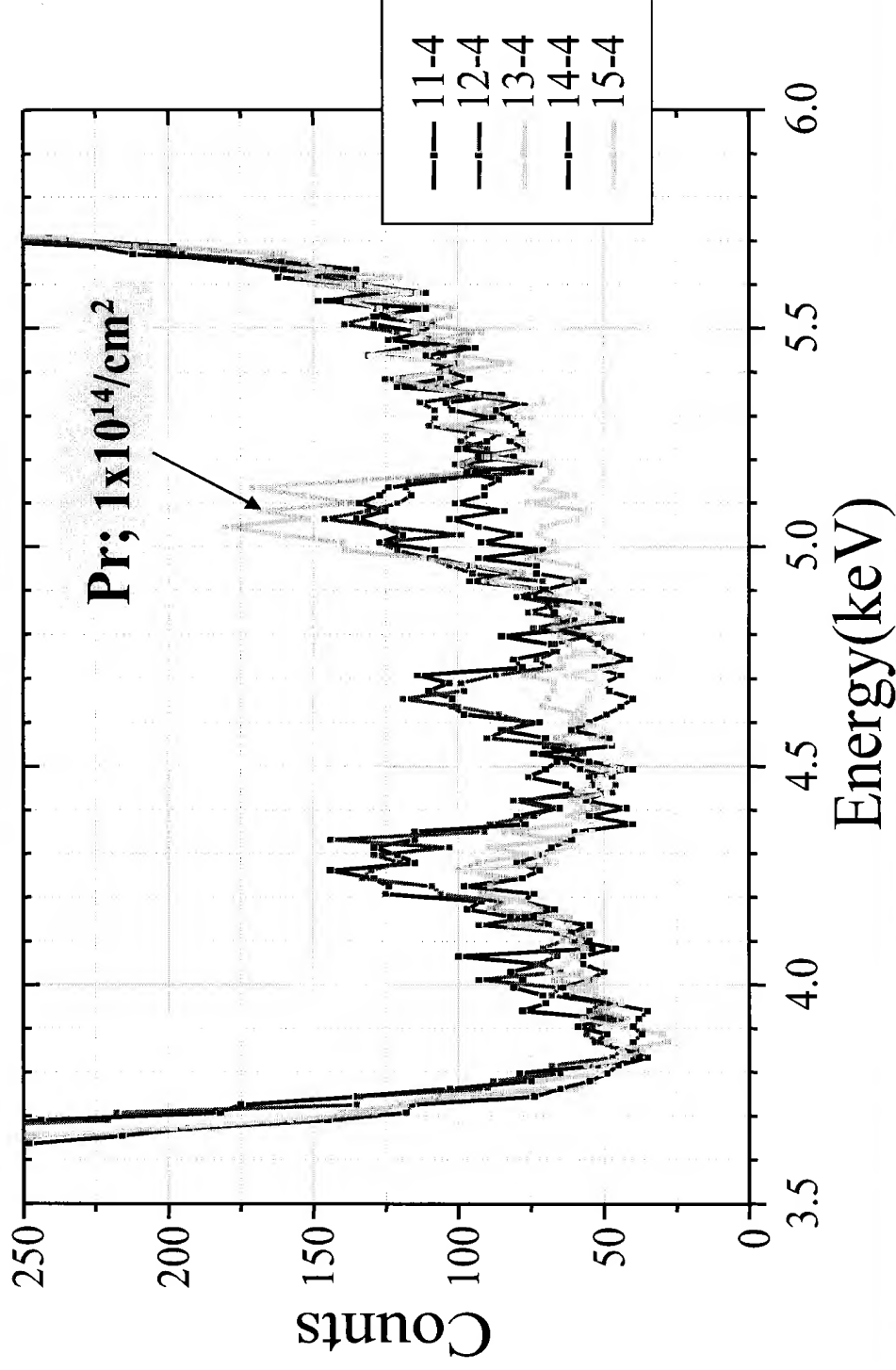
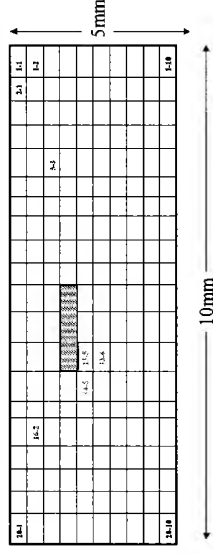
## X-ray Beam; SP-24 (*in-situ* Exp.)



Red : Detection of Pr only; 6points (3%)  
 Blue : Detection of Pr and unidentified element; 2points (1%)  
 Black : No Detection; 192points (96%)

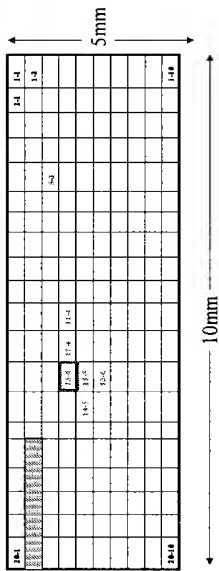
# Pr detection, SP-24, 500 micron beam

Point from 11-4 to 13-4

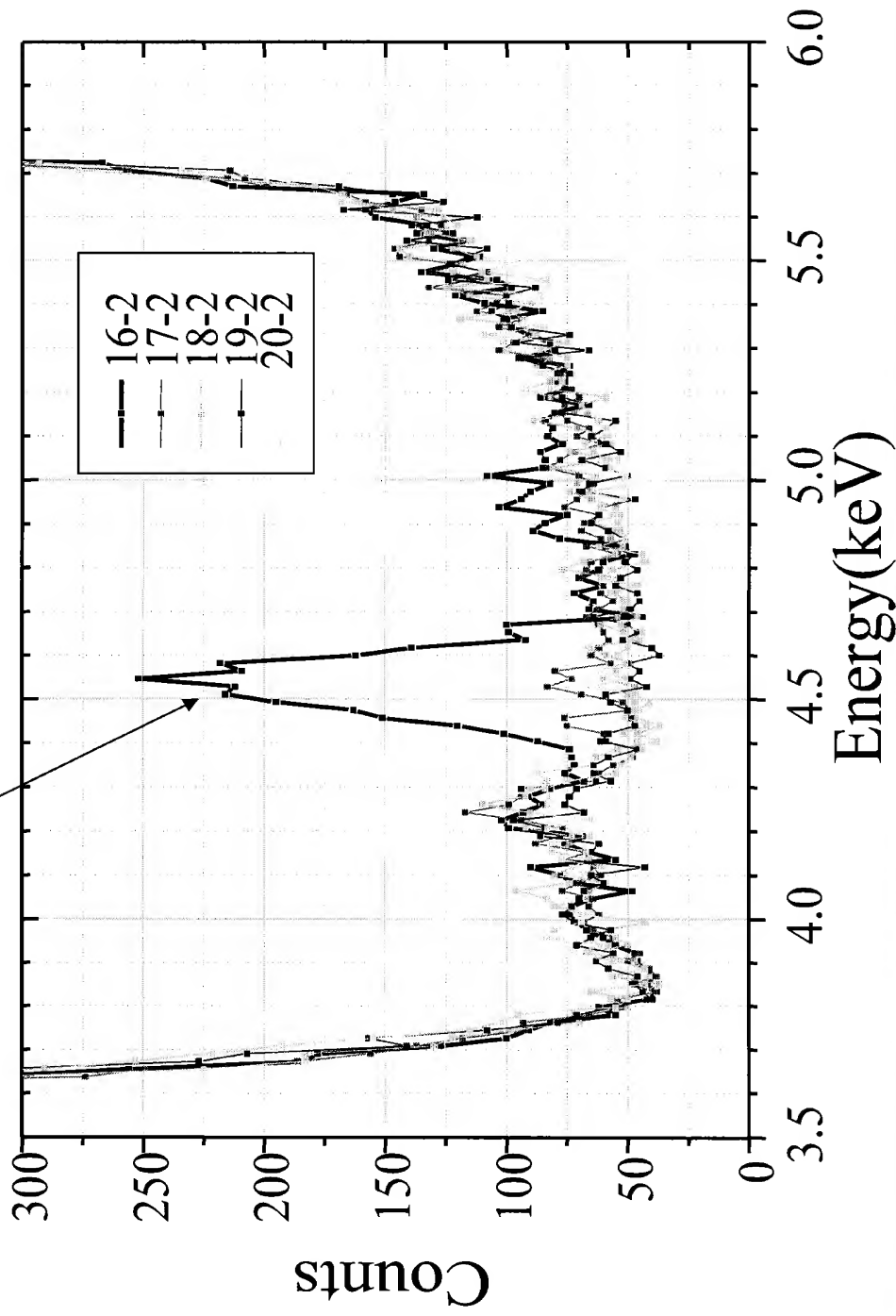


# Unidentified Peak, SP-24, 500 micron ~~INSTRUMENTAL~~ **SHIMADZU** **CO.** **TECHNICAL HEADQUARTERS**

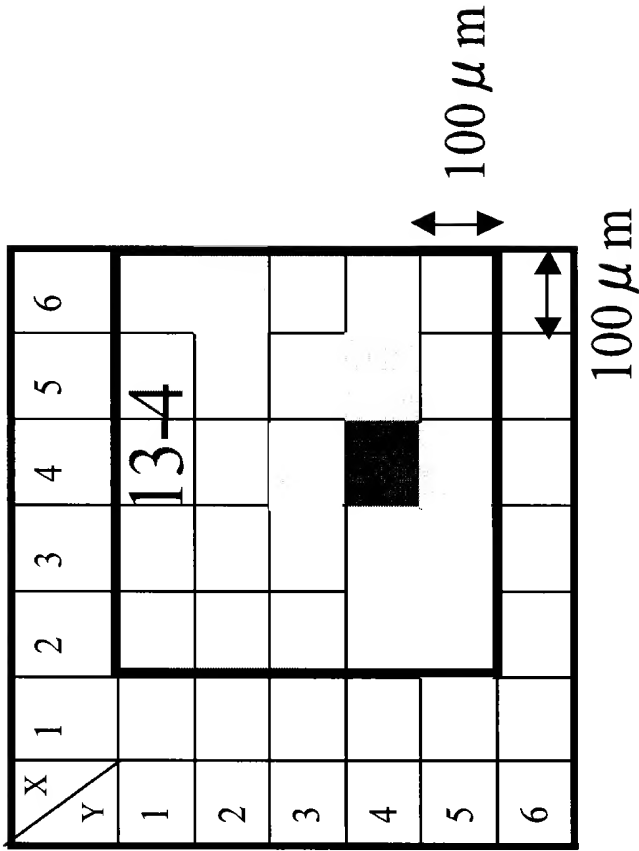
Point from 16-2 to 20-2



Unidentified Peak at 16-2



100 micron beam;SP-24, 13-4

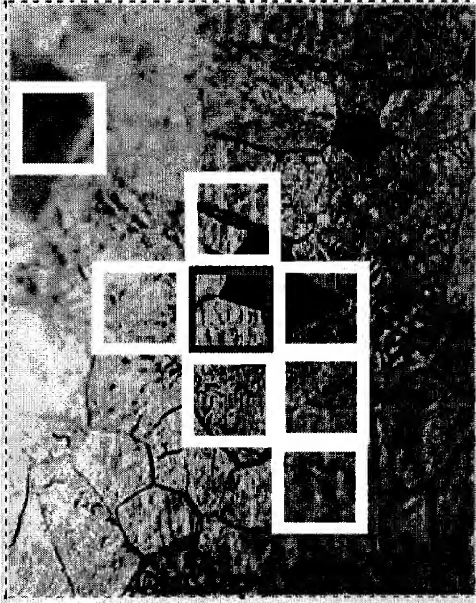


Much Pr detection

Pr detection

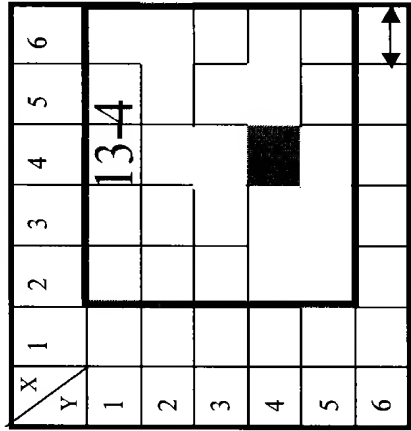


No Pr

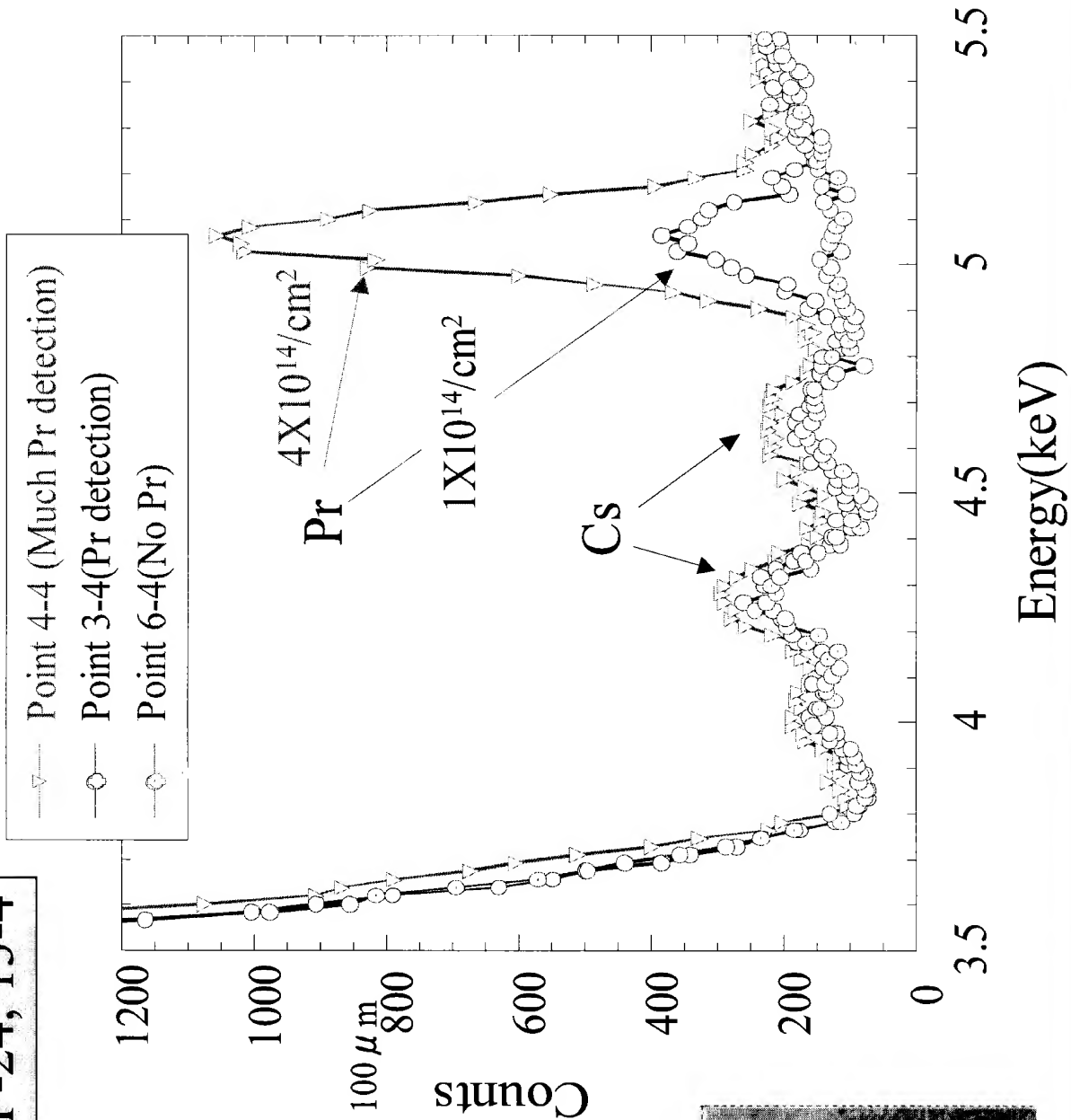
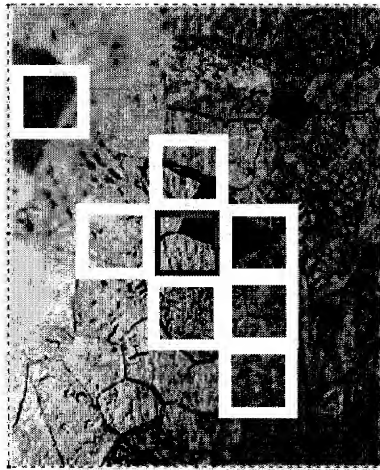


If we use smaller size X-ray beam, we can see that Pr is localized.

100 micron beam; SP-24, 13-4

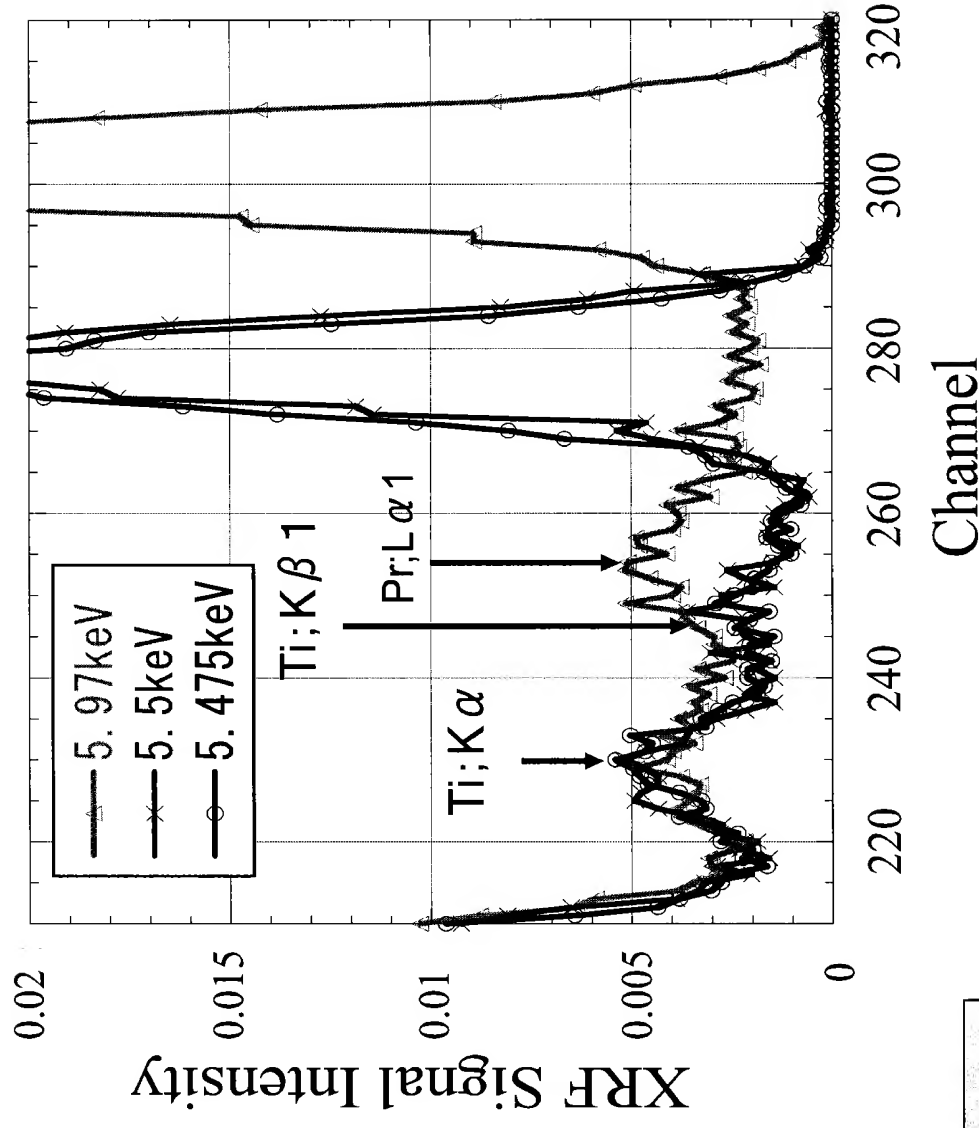


Much Pr detection  
 Pr detection  
 No Pr

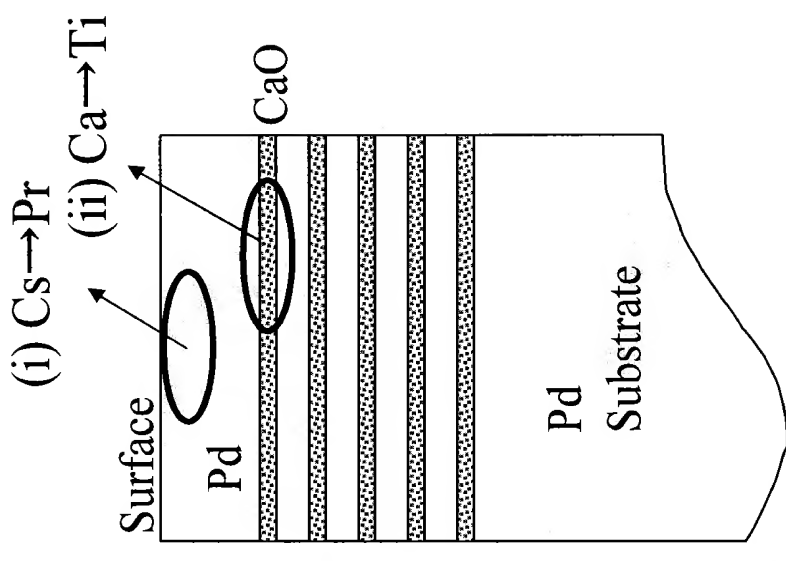
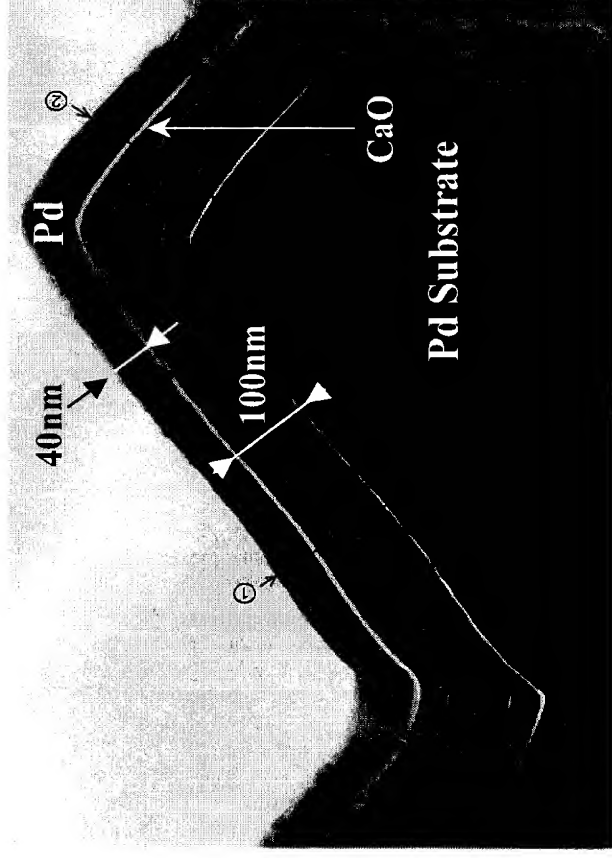


# Identification of the unidentified Peak

## by Energy Scan XRF



# Possible Origin of the detected Ti



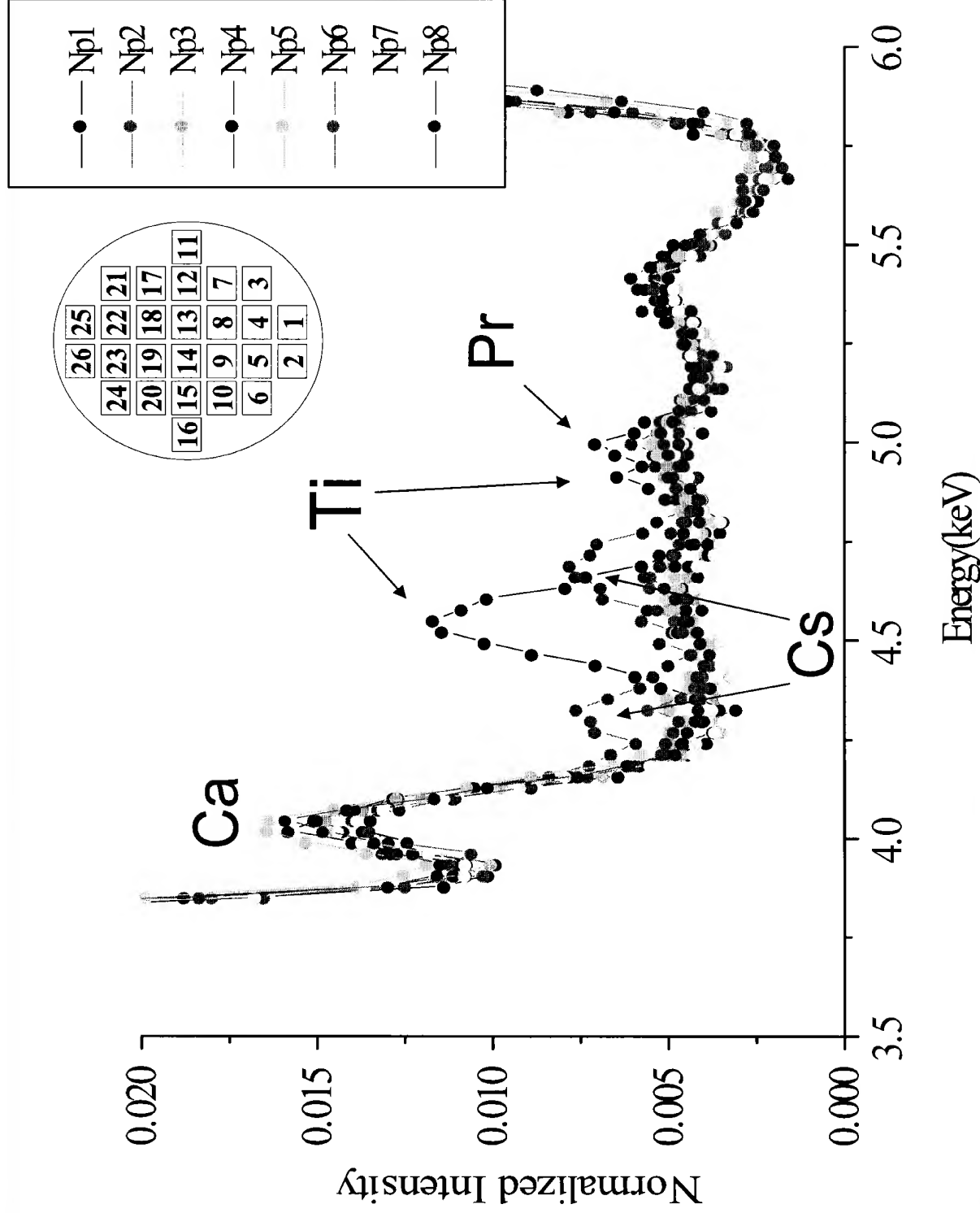
Ti could be transmuted from Ca inside



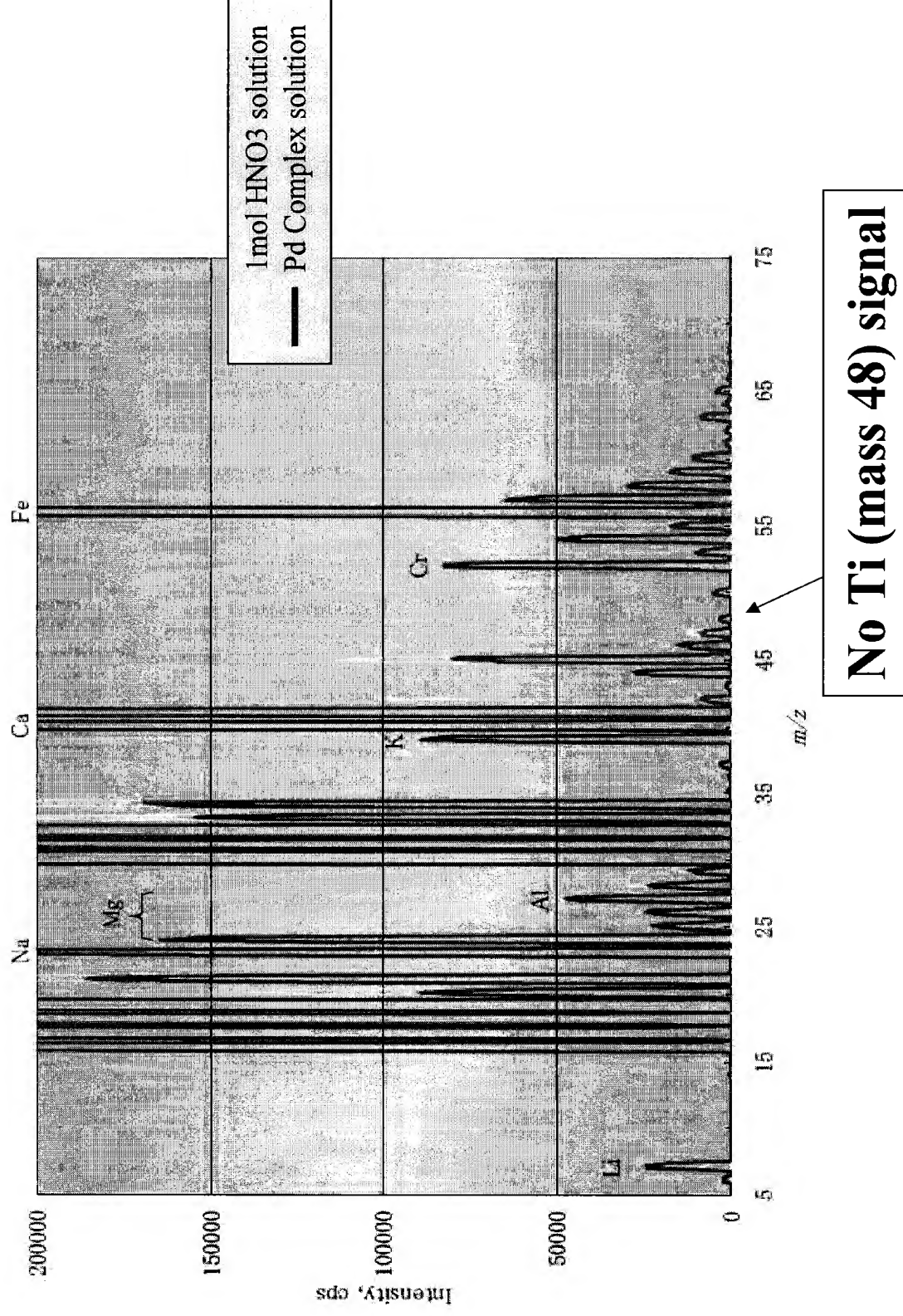
Deeper region transmutation?



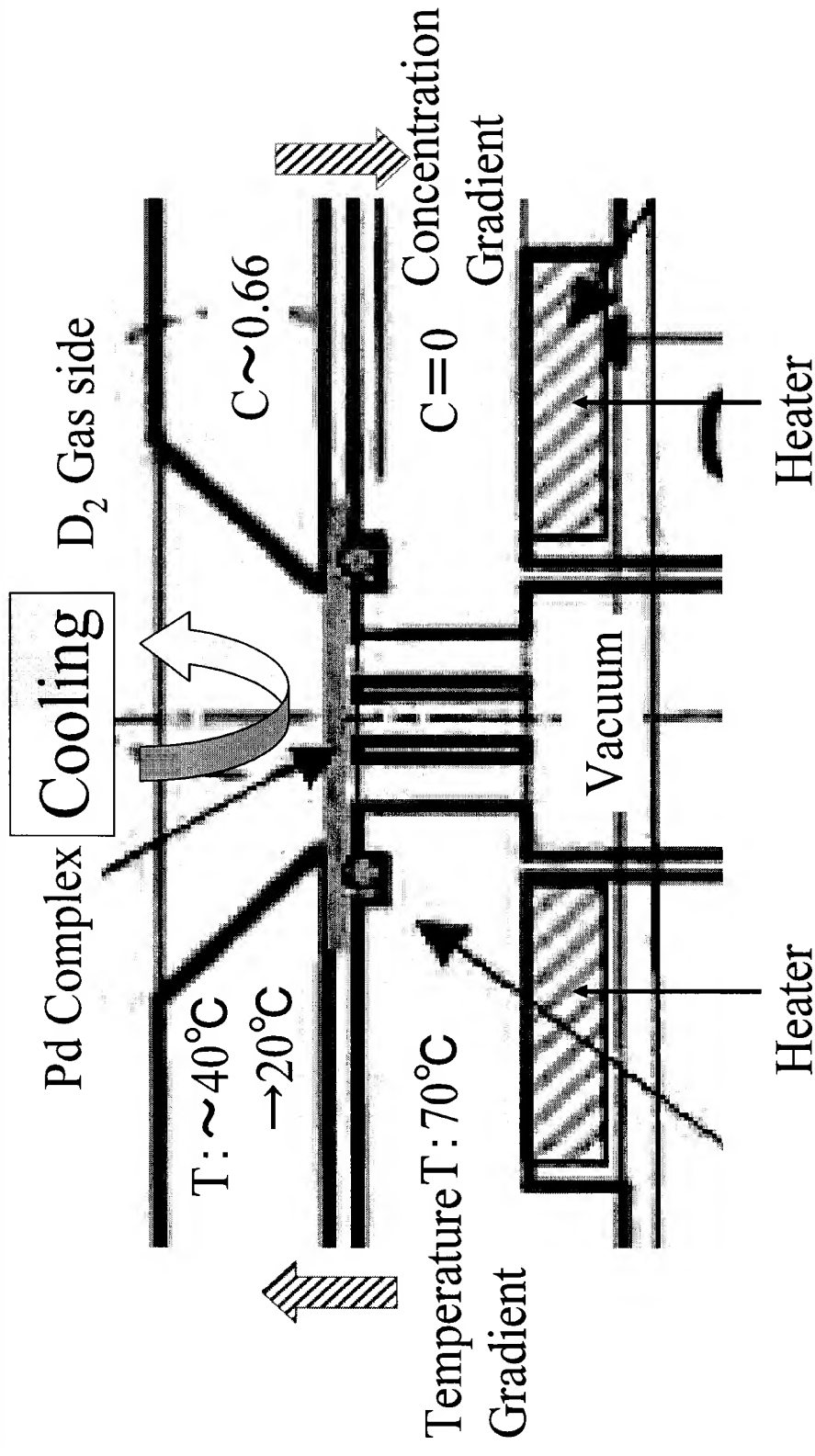
# Detection of Pr and Ti by XRF



# Impurity Analysis of a Pd complex before permeation by ICP-MS



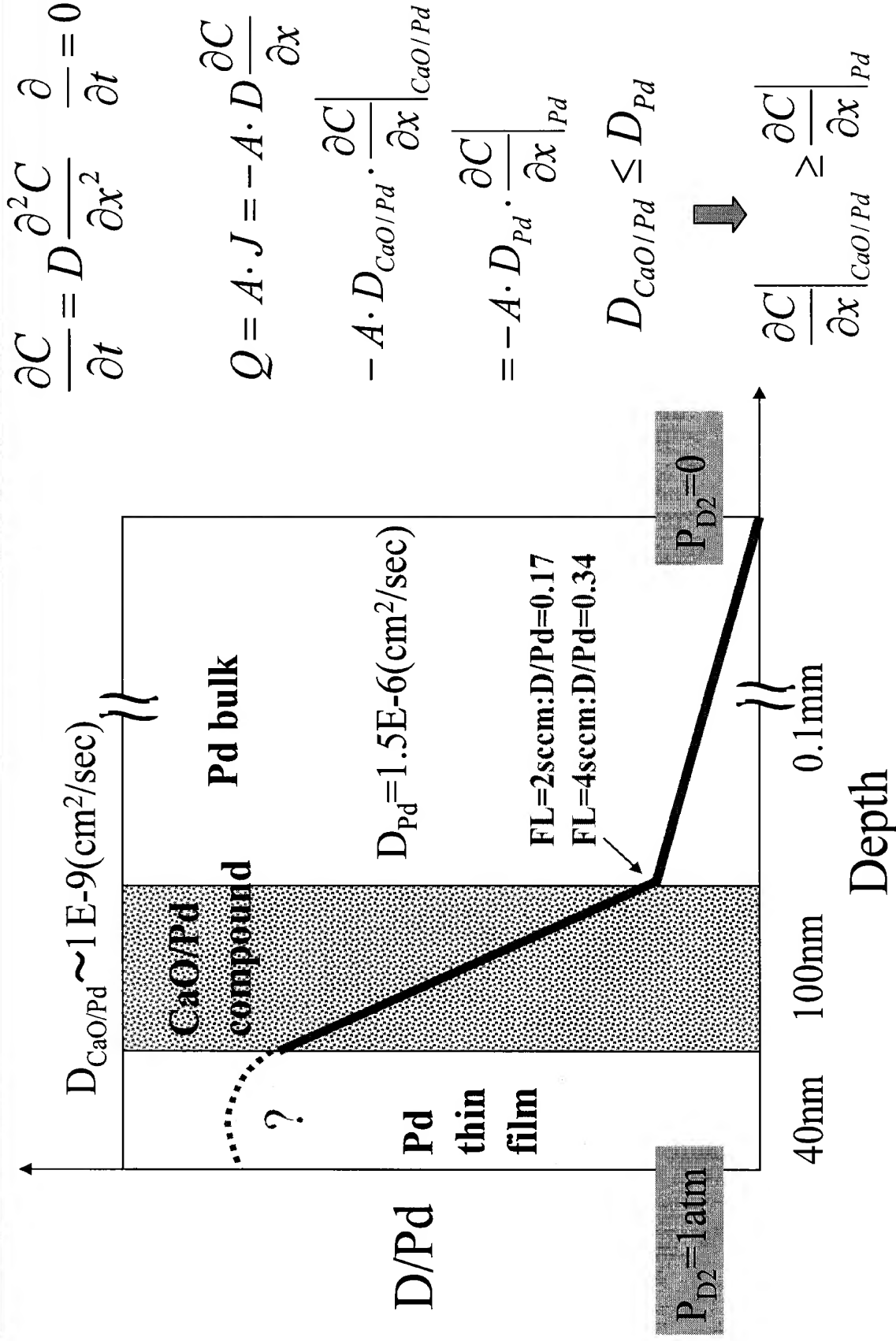
# Effect on D density by gradient T



Density of D on the D2 side surface would be increased.

$$\begin{aligned} \mathbf{J} &= \mathbf{J}_{diffusion} + \mathbf{J}_{drift} = -nD\nabla c + ncM\mathbf{F} \\ &= -nD\left(\nabla c + \frac{cQ^*\nabla T}{k_B T^2}\right) \quad Q^* : \text{Heat of Transport} \end{aligned}$$

# D distribution in the Pd Complex



D distribution will be observed by using the Nuclear Resonance Reaction at Univ. of Tokyo.

# Concluding Remarks

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1. Low energy nuclear transmutations from Cs into Pr, Sr into Mo and Ba into Sm have been observed in the Pd complexes, which are composed of Pd and CaO thin film and Pd substrate, induced by D2 gas permeation through Pd multilayer complexes.
  2. “In-situ” measurement of transmutation of Cs into Pr and surface distribution of Pr were investigated using X-ray Fluorescence Spectrometry at SPring-8. Unidentified Peaks except Pr were observed in some cases.
  3. The unknown peak was identified as Ti by Energy Scan XRF. Ti could be supposed to be transmuted from Ca inside the Pd Complex. Transmutation reactions at deeper region might be induced.
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